

Dredging Research

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TrophicTrace models contaminant bioaccumulation, trophic transfer, and risk

A new tool, now available to scientists, engineers, and managers, promises to facilitate more quantitative evaluations and interpretation of bioaccumulation data. Research staff at ERDC Vicksburg's Environmental Laboratory developed

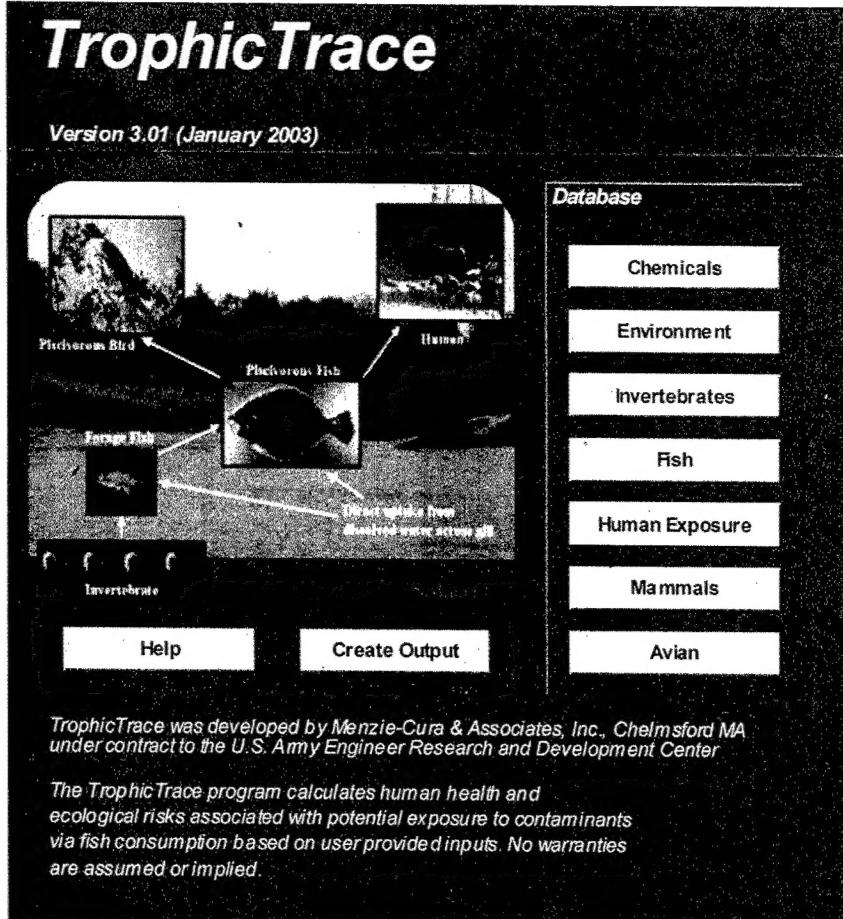
TrophicTrace, a flexible modeling tool for risk-based evaluations of bioaccumulation data.

Dr. Todd Bridges, research scientist, said: "Let's assume you've just spent a sizable sum of money conducting a bioaccumulation test for your dredged material. The data have passed quality assurance

review and now sit on your desk ready for your analysis and interpretation."

Bridges explained that the current approach for evaluating dredged material involves comparing contaminant concentrations in test organisms that were exposed to dredged material to action levels (for example, action levels to meet Food and Drug Administration standards, or others). If relevant action levels are not exceeded, a comparison is made to tissue concentrations in organisms exposed to a reference sediment. The reference comparison provides a simple method for determining that a dredged material is suitable for open-water placement when no statistically significant bioaccumulation is observed in animals exposed to the dredged material.

If, however, significant bioaccumulation is observed in organisms exposed to dredged material, the "Ocean Testing Manual" and the "Inland Testing Manual" provide qualitative guidance for evaluating the likelihood that statistically observed bioaccumulation would result in unacceptable risk to human or ecological receptors.



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According to Bridges, the likelihood for significant adverse effects from bioaccumulation will depend on many specific features of the project, sediment, and disposal site. For example, the volume of material to be dredged and disposed, contaminant concentrations in tissue in relation to toxicological benchmarks, as well as the nature and frequency of site-use by ecological or human receptors of concern all play a significant role in assessing potential risk. *TrophicTrace* is a tool that District personnel and regional stakeholders can use in combination with existing risk assessment guidance. When using the model to assess risks posed by a specific sediment, site-specific information must be entered. Such data include regional food web structure and exposure parameters for human and ecological receptors. Bridges said, "We expect that local and regional stakeholders will parameterize *TrophicTrace* for their site-specific and region-specific needs and applications."

TrophicTrace is an Excel™ add-in that provides a spreadsheet tool for calculating the potential human health and ecological risks associated with bioaccumulation of contaminants in sediment. The model provides incremental lifetime cancer risks and hazard indices for noncarcinogenic human health effects via

the fish ingestion pathway. The tool also includes an ecological receptor module for assessing risk to fish, avian, and mammalian receptors.

For organic contaminants, bioaccumulation and trophic transfer can be modeled starting with sediment concentrations or tissue data from bioaccumulation tests. The model used to estimate fish body burdens from such data relies on a steady-state uptake model based on the approach of F.A.P.C. Gobas, whose 1993 publication, *A model for predicting the bioaccumulation of hydrophobic organic chemicals in aquatic food-webs: Application to Lake Ontario*, appeared in *Ecol. Modelling* 69, pages 1-17.

TrophicTrace also includes an option that allows the use of Biota Sediment Accumulation Factors to estimate benthic invertebrate tissue concentrations. Estimates of fish burdens for inorganic and hydrophilic organic compounds rely on two different approaches, depending on data availability. The first approach uses a trophic transfer

factor to move contaminants between prey and predator, and the second uses a bioconcentration factor (BCF) approach. In the BCF approach, water concentrations are multiplied by a BCF to estimate fish body burdens. Water concentrations can either be provided by the user or estimated by the model assuming equilibrium partitioning from user-input sediment concentrations.

Standard equations and algorithms assess human and ecological effects within *TrophicTrace*. Risks to humans can be estimated for cancer and noncancer endpoints. For ecological receptors, toxicity reference values can be used to assess risk as hazard quotients.

To address the issue of confidence in modeled estimates of risk, *TrophicTrace* incorporates interval analysis, or "fuzzy math," algorithms to quantify uncertainty. Instead of entering simple point estimates for parameters, users can enter "possible" and "probable" ranges for input values, resulting in risk estimates with associated uncertainty.

TrophicTrace and associated documentation can be downloaded at <http://www.wes.army.mil/el/trophictrace/index.html>. Additional information is available from Dr. Todd S. Bridges, Todd.S.Bridges@erdc.usace.army.mil, telephone 601-634-3626.

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Palos Verdes capping pilot study successful: Breaks record for capping in deep water

A portion of the Palos Verdes Shelf is a highly contaminated U.S. EPA "superfund site" off the coast of Los Angeles, Calif. The parties responsible for site contamination had been sued by the government, but settled out of court, primarily on the basis of studies evaluating subaqueous capping as a remedial alternative. As a part of this effort, the Palos Verdes Pilot Cap Study was performed. This study included extensive modeling and monitoring, sampling and analysis, and dredging and cap placement at full scale. By April 2000, the team included 12 key individuals, and more than 40 support individuals from the Corps' Los Angeles, New England, and Seattle Districts and ERDC Vicksburg's Environmental and Coastal and Hydraulics Laboratories. The study included dredging contractor support from Chicago and Long Beach, Calif., and monitoring contractor support from Newport, R.I., and San Diego. Through effective communication and coordination, the pilot cap placement and initial post-placement monitoring was successfully completed by September 2000.

The project began several years ago, when the U.S. EPA Region 9 investigated the feasibility of in situ capping in all or a portion of the DDT- and PCB-contaminated sediments on the Palos Verdes Shelf. In September 1999, U.S. EPA entered into an Interagency Agreement with the Corps of Engineers to perform a pilot study of in situ capping. This \$5-million Palos Verdes Pilot Cap Study took place in the summer of 2000. The evaluation included

- Prioritizing areas of the Palos Verdes Shelf to be capped
- Determining appropriate cap designs
- Developing an equipment selection and operations plan for placement of the cap
- Developing a monitoring plan to ensure successful cap placement and long-term cap effectiveness
- Developing preliminary cost estimates.

The pilot study involved placement of approximately 103,000 cu m (135,000 cu yd) of capping sediments in three 18-ha (45-acre) capping cells situated at water depths between 40 and 70 m. Capping at these water depths had never before been attempted. To accomplish this placement, technically complex activities had to be performed, including dredging suitable cap material and modeling of cap material to predict cap placement. In addition, extensive monitoring, sampling and analysis of sediments and water column, and development and maintenance of a geographic information system database were performed.

The project site was located near sewage outfall diffusers owned by Los Angeles County Sanitation District, which discharges more than 350 million gallons per day. Test cells had to be located in areas where activities would not interfere with the sewage outfall diffusers.

The possibility of negative impacts to the environment brought attention and scrutiny from environmental advocacy interest groups. The project attracted significant media attention, both locally and nationally (front page of *Los Angeles Times*, local TV news broadcasts, articles in national newsletters). Media coverage was mainly positive, which was a tribute to the successful information outreach efforts of the project delivery team.

Team effort resulted in the concept to combine cap placement for this project with the Port of Long Beach main channel deepening project, resulting in cost savings of \$11.6 million to the agencies.

The final objectives for the pilot study were to

- Demonstrate constructability of a cap with varying thickness
- Demonstrate that resuspension of contaminated sediments, or mixing of native contaminated sediments and cap, can be avoided
- Demonstrate that excessive losses of cap materials can be avoided

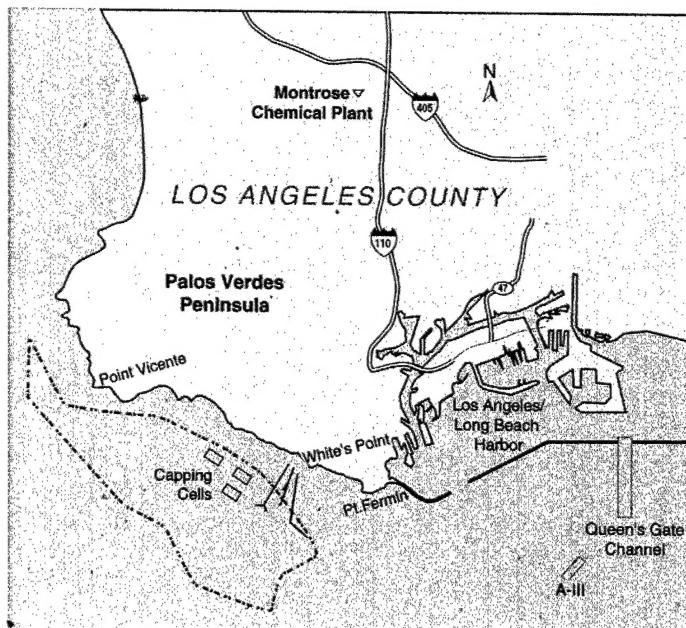


Figure 1. Location map showing Palos Verdes shelf and slope, pilot capping cells, Queen's Gate entrance channel, and borrow area A-III.

- Determine the effect of variables, including cap material and type, bottom slope, water depth, and placement methods, with respect to cap thickness and resuspension
- Demonstrate effectiveness of cap with respect to short-term isolation of contaminants
- Demonstrate ability to monitor operations of cap placement
- Evaluate and modify operations and monitoring approaches
- Improve the knowledge base contributing to decisions on implementing a full-scale cap.

Two capping approaches were considered for selected areas of the shelf: placement of a thin cap (design thickness of 15 cm), which would isolate the contaminated material from shallow burrowing benthic organisms, providing a reduction in both the surficial sediment concentration and contaminant flux; and placement of an isolation cap (design thickness of 45 cm), which would be of sufficient thickness to effectively isolate the majority of benthic organisms from the contaminated sediments, prevent bioaccumulation of contaminants, and effectively prevent contaminant flux for the long term. These design cap thicknesses were considered in setting target cap thicknesses for the pilot study. After consideration of all options, the final pilot project was composed of three cells, LU, LD, and SU. The location of the cells within the effluent-affected (EA) sediment footprint is shown in Figures 1 and 2. Pilot placements occurred within the limits of these three cells (with the exception of a single hopper pump-out load placed between cells LU and LD).

Cap Material Requirements

Use of dredged material from ongoing navigation projects would be far less expensive than excavation from borrow sites because the operational cost attributable to the pilot would be limited to the difference in transportation and disposal cost to the Palos Verdes Shelf as compared to the selected disposal sites. But use of dredged material from an ongoing project would be dependent on close coordination of navigation dredging schedules and contracts. Use of dredged material from an approved navigation project could also be advantageous for the overall schedule, as the dredging impacts in the channel areas and ocean disposal of the sediments would have already been evaluated, thus making the National Environmental Policy Act process and other regulatory considerations for the pilot project more straightforward.

The Queen's Gate channel deepening project was the only ongoing navigation project identified with sufficient volumes of clean material to conduct the pilot project. The Queen's Gate material had an in situ mean

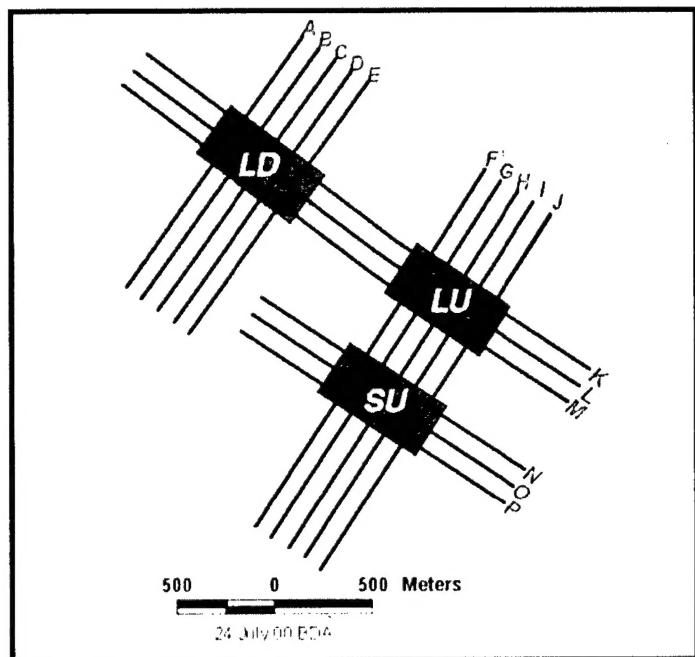


Figure 2. Relative locations of pilot capping cells LD, LU, and SU

grain size of approximately 0.1 mm. Modeling had indicated that the Queen's Gate material could be used for cap construction if the conventional method of placement was used. Los Angeles District personnel indicated that the finer material mixtures from Queen's Gate may be representative of much of the material available from the borrow areas inside the harbor. Therefore, in the context of the pilot, use of Queen's Gate was appropriate for demonstration of conventional placement techniques using the type of finer material available in the Los Angeles region.

Sand borrow areas located outside the harbor breakwaters have in situ mean grain sizes in excess of 0.2 mm. However, these materials are also highly variable, and there are environmentally sensitive areas located within the larger borrow areas corresponding to submerged aquatic vegetation and rock "pinnacles" with high fisheries values. Borings in selected portions of borrow areas (water depths less than 80 ft (24.4 m) and outside known sensitive areas) identified a source of coarser material for the pilot, shown as borrow area A-III in Figure 1.

Modeling conducted prior to final cap material selection indicated that a spreading placement for mixtures of fine sand and silt/clay cap material (such as material from Queen's Gate) resulted in a larger proportional dispersion offsite, and potentially greater spread downslope as compared to a coarser sand (such as from the sand borrow areas). Therefore, the finer materials were selected for placement using conventional release from the hopper dredge. The coarser borrow area materials from A-III were selected for placement by spreading.

Environmental Coordination

The proposed capping operations for the pilot study and the associated requirements to borrow capping material from the Queen's Gate channel and other borrow sites required appropriate environmental coordination and the preparation of several environmental coordination documents. Use of the Queen's Gate dredged materials for the pilot study involved modifying a previously assessed project (the Port of Long Beach's main channel deepening project). An Environmental Impact Statement was prepared for the underlying project, and a Supplemental Environmental Assessment was prepared to address impacts and develop mitigation (if warranted) associated with proposed modifications, i.e., material transport to the Palos Verdes Shelf. Coarse sand obtained from borrow site A-III was assessed as a new and separate, although related, project. An Environmental Assessment was prepared to address impacts and develop mitigation (if warranted) associated with proposed modifications, i.e., dredging of borrow material and transport to the Palos Verdes Shelf.

Selection of Placement Equipment

Hopper dredges were identified as a preferable placement equipment type, and use of a hopper dredge was planned for the pilot study. A hopper dredge was the equipment of choice for the pilot study for the following reasons:

- Hopper dredges were the most readily available equipment for the pilot work.
- Hopper dredges provide better control of placement in the open ocean environment and allow for more flexibility in placement options to include pump-out capabilities.
- Hopper dredges remove material from channels by hydraulic means, resulting in a breakdown of any hard-packed material and addition of water as material is

stored in the hopper for transport. Material from hopper dredges is therefore more easily dispersed in the water column, and therefore potentially settles to the seafloor with less energy and less potential for resuspension of the contaminated sediment than mechanically dredged sediments.

Target Cap Thickness and Volume

Two objectives of the pilot study were primary drivers in determining the target volumes and thicknesses of material necessary for placement for the pilot: the need to determine differences in cap material behavior for differing placement options, and the need to determine the volume of material required to construct a full design cap thickness over a given area. Time and cost limitations for the pilot study made it impractical to undertake construction of the full cap design thickness of 45 cm for each possible combination of cap material type, water depth, bottom slope, and placement technique. The pilot study activities were therefore scoped to ensure that the effort remained within budget.

The pilot study included a combination of small placement volumes and larger placement volumes. It was determined that data on various placement methods and variable material types should be obtained from a few hopper placements with small placement volumes. The most likely placement method and mate-

rial type to be employed full scale were evaluated for construction of a full cap design thickness over a sufficient area to determine the process of cap thickness buildup for adjacent placements. Since the bottom slope only moderately increases with water depth for areas between the 40- and 70-m depth contours, it was deemed that a comparison of shallow and deeper placement areas for the pilot study would provide the needed information for both depth and, to some degree, bottom slope.

The fieldwork for the baseline monitoring in the pilot capping cells began in mid-May 2000, although the baseline sediment profile and plan view photos were not taken until a few days before cap placement started. The monitoring program during cap placement involved 59 trips by survey vessels, with as many as three survey vessels onsite at any one time. The bulk of the near-term postcap monitoring activity was completed September 15, 2000, a few days after the last load was placed in cell LU. In early March 2001, additional sediment cores and sediment profile photos were collected to better define cap thickness and distribution, as well as to assess short-term benthic recolonization of the cap material. A second postcap placement monitoring effort to address problems with coring artifacts seen in early sampling efforts was conducted in March 2002.

Summary of capping activity conducted during the pilot study

Cell	Water Depth	Cap Material	Placement Method	Projected Cap Thickness/Area	No. of Loads	Volume (cu m)
LU	Shallow 45 m	Queen's Gate	Conventional	15-45 cm (6-18 in.) over entire cell	71	69,815
LD	Shallow 45 m	Borrow site	Spreading	≤10 cm in center lane only	9	10,325
	Shallow 45 m	Queen's Gate	Pump-out thru drag arm	n/a (1 load only)	1	298
SU	Deep 60 m	Queen's Gate	Conventional	15 cm in center portion of cell	21	22,810
				Total	102	103,248

Modeling

The mathematical model MDFATE was used to predict the rate of cap material buildup for specific sediment characteristics, various water depths over the shelf, and various placement approaches. The STFATE and SURGE models were used to predict cap material dispersion during placement and evaluate the velocities of bottom impact on spreading behavior, respectively. These predictions were initially based on a broad range of assumed properties for the cap material. Once specific cap material sources were selected, refined predictions using the specific site conditions and cap material properties were made using the MDFATE, STFATE, and CORMIX models. Results of the refined predictions were used to adjust the operational approach and monitoring efforts for the pilot study.

Summary of Findings

A preliminary summary of the results, in terms of the key questions to be answered by the monitoring program, is presented below:

Does placement occur as modeled? The actual behavior of the released sediment compared very well to the predictions made by numerical modeling. These predictions included: distribution of cap material on the seafloor, decrease of surge velocities as a function of distance from the placement location, and dilution of the plume to near background conditions within 2 to 3 hr of cap placement.

Can a uniform cap be constructed? Evidence from the sediment profile, coring, and side-scan surveys supports a conclusion that it will be possible to create a cap on the Palos Verdes Shelf that is quite uniform. The caps that were created using both conventional and spreading placement generally vary in thickness by only a few centimeters across those areas that received what could be considered a full cap application during the

pilot study, this being the central portion of cells LU and SU and the central axis of cell LD. It does appear that the use of spreading placement may result in a cap that has somewhat greater uniformity than one created with conventional placement.

The cap placement spacing, which was based on modeling and the results of these initial field surveys, appeared to be reasonable for helping attain a uniform cap. Single placement events resulted in cap thickness increases of only a few centimeters when the material was released immediately around the placement point while the vessel was stationary. By spacing the neighboring placement points such that the bottom surge areas would overlap with those points around it allowed gradual buildup of the cap from these multiple events. This approach was likely a large contributor to the uniform caps. We did observe some areas during the capping operation that had thinner thicknesses of cap, particularly at two stations in cell SU. If the pilot effort had been focused on placing a full remediation cap in those areas, we would have directed additional sediment to these locations and may also have considered spreading, releasing it more slowly, and perhaps while underway to help to achieve greater evenness.

Can disturbance to in-place sediments be kept within tolerable limits? Some physical disturbance to the EA sediment was observed, but this appeared to be within expectations of only a few centimeters. This disturbance was minimized during the pilot study through the management of cap placement points. In addition, it appears that the spreading placement approach has the potential to result in even less disturbance to in-place sediments than conventional placement.

Disturbance to the EA sediment was evident in the sediment-

profiling imaging (SPI) photographs and in the cores. SPI photos were able to observe the partial or complete loss of the 2- to 3-cm-thick precapping sediment oxidized layer at some of the stations. This observation was particularly evident at stations close to the first few cap placement points in cells LU and SU. However, once subsequent cap began to occur only over bottom with areas where cap laterally surged from prior events, there appeared to be some protection provided to the EA sediment that lessened the disturbance. Spreading placement in cell LD appeared in SPI photos to result in even less disturbance to the EA sediments. This is certainly a result of the smaller mass of sediment released over any given area and the slower impact and surge velocities.

Water quality measurements also support a conclusion that the impact to the EA sediments was acceptable. The highest occurrence of DDE in the resuspended water column plume in cell LU occurred on the very first placement event. The observed value was $0.29 \mu\text{g/l}$, about two orders of magnitude greater than background of $0.005 \mu\text{g/l}$. Subsequent measurements in the same plume showed a rapid return to background levels. The next monitored events in cell LU appeared to result in much less resuspension of EA sediment as peak concentrations were about an order of magnitude less (0.017 and $0.010 \mu\text{g/l}$) than the first event and only two to three times greater than background. These placement events occurred in the same location as the previous three events, and the EA sediments were likely shielded from direct impact by the cap already in place. Similarly, monitoring of the plume in cell SU observed a peak value of DDE immediately following the first disposal event with levels nearing background within about 30 min.

Does the cap remain clean? Other than a certain degree of mixing that occurs with the initial layers of cap that are placed, we were able to achieve a clean cap. The process of cap placement resulted in about 3 to 4 cm of the cap becoming mixed to some degree with the EA sediment. As cap thickness increased beyond this, mixing with the EA sediment became negligible such that the upper portions of the cap had very low levels of DDE.

Does the cap remain stable during placement? We observed no evidence of cap or EA sediment instability as a result of operations. Current surge monitoring results indicate that the energy from the cap placement decays with distance and time away from the point of release. This lessens concerns about the potential to trigger downslope turbidity flows. We did observe that at the steeper sloped cell SU, the current speed decay was not as prominent. If the issue of turbidity flow creation does remain an unacceptable concern, use of spreading placement, which produced considerably lower surge velocities, would be the recommended option in such locations.

None of the other tools used to observe the state of the EA sediment and cap (SPI, plan view camera (PVC), side-scan, or sub-bottom profile) provided any indication of sediment instability. We observed no large-scale deformations or changes in the seafloor, around the cells, and in particular downslope. Beyond the cap margins, SPI and PVC showed an ambient seafloor that was unaffected by the physical process of multiple capping events that had gone on nearby and at a distance of only 10's of meters.

Additional Details and Next Steps

U.S. EPA and the Corps are currently reviewing and evaluating the data collected for the pilot project. Complete results for the project and pilot study will soon be available in reports prepared for U.S. EPA by the Corps and its contractors. The Corps' pilot study evaluation report is available online at <http://www.wes.army.mil/el/elpubs/pdf/tr02-5.pdf>.

Additional information is available from Dr. Michael R. Palermo. This article is based in part on a paper presented at ASCE Dredging 2002 Conference. For a copy of the full article, contact Mike Palermo, at Michael.R.Palermo@erdc.usace.army.mil.



Dredging Calendar

March 30-April 3 – 13th International Harbour Congress, Provincial House, Antwerp, Belgium. For further information contact: Ms. Rita Peys, Conference Manager, Technological Institute - KVIV Ingenieurshuis, Desguinlei 214, B-2018 Antwerp, Belgium, tel. +32 3 260 08 40, fax +32 3 216 06 89, e-mail: rita.peys@ti.kviv.be, hav@conferences.ti.kviv.be, www.ti.kviv.be/conf/haven.htm.

April 8-10 – Workshop on Environmental Stability of Chemicals at the Wyndham San Diego. Information and registration forms can be found at www.sediments.org/env-stab.html.

April 13-16 – Inaugural National Conference on Coastal and Estuarine Habitat Restoration, Baltimore, MD, Hyatt Regency Inner Harbor. The conference is the first nationwide forum focused solely on the goals and practices of coastal and estuarine habitat restoration. POC: Rick Bates, Development Director at Restore America's Estuaries, at (703) 524-0248, e-mail: rickbates@estuaries.org.

April 15 – Application deadline for Gulf Guardian Award. Sponsored by the partnership of the Gulf of Mexico Program to recognize environmental stewardship in the five Gulf Coast States. For more information visit www.epa.gov/gmpo.

May 12-14 – In-situ Contaminated Sediment Capping Workshop, Cincinnati, Ohio. Sponsored by EPA, USACE, and NOAA. POC: Donna Peterson, EPRI Processing, 1355 Willow Way, Suite 278, Concord, CA 94520-5728, e-mail: meeting@epri.com.

April 30, 2003 – Deadline for abstracts

June 30, 2003 – Replies to authors

November 30, 2003 – Deadline for full papers

August 2-6, 2004 – International Symposium on Sediment Transfer through the Fluvial System, Moscow, Russia.

Sponsored by The International Association of Hydrological Sciences (IAHS), International Commission on Continental Erosion (ICCE), and co-sponsored by Moscow State University. Contact and information: Valentin Golosov or Vladimir Belyaev at tel. 007-095-9395044, fax 007-095-9395044.

May 26-28 – 2d International Symposium on Contaminated Sediments. Loews Le Concorde Hotel, Quebec City, Canada. Sponsors: ASTM, CGS, CSCE, SRA-SETAC. POC and information can be found at www.scs2003.ggl.ulaval.ca/SCS2003_English.pdf.

June 4-6 – OI Americas 2003. Morial Convention Center, New Orleans, Louisiana, USA. To receive further information contact www.woda.org or CEDA, P.O. Box 488, 2600 AL Delft, The Netherlands, tel. +31 15 278 3145, fax +31 15 278 7104, e-mail: ceda@dredging.org.

June 11-13 – WEDA XXIII and Texas A&M's 35th Annual Dredging Seminar, Chicago, Ill. Program theme is *The Dredging Contractor*. For additional information contact Lawrence M. Patella, tel. 360-750-0209, fax 360-750-1445 or visit www.westerndredging.org.

July 13-17 – Coastal Zone 03, Baltimore. Convention Center located in the Inner Harbor District at One West Pratt Street. Theme of conference is "Management through time: Port and harbor, regional land, management response to coastal hazards (erosion), and management of aquatic resources. More information can be found at www.csc.noaa.gov/cz2003/information.html.



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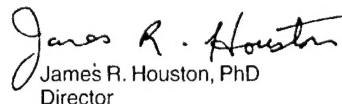
Articles for *Dredging Research* requested:

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Articles from non-ERDC authors are solicited for publication, especially if the work described is tied to the use of ERDC-generated research results. Research articles that complement ERDC research or cover wide field applications are also accepted for consideration. Manuscripts should use a nontechnical writing style and should include suggestions for visuals and an author point of contact. Point of contact is Elke Briuer, APR, at *Elke.Briuer@erdc.usace.army.mil*.

Dredging Research

This bulletin is published in accordance with AR 25-30 as an information dissemination function of the Environmental Laboratory of the U.S. Army Engineer Research and Development Center. The publication is part of the technology transfer mission of the Dredging Operations Technical Support (DOTS) Program and includes information about various dredging research areas. Special emphasis will be placed on articles relating to application of research results or technology to specific project needs. The contents of this bulletin are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or the approval of the use of such commercial products. Contributions are solicited from all sources and will be considered for publication. Editor is Elke Briuer, APR, *Elke.Briuer@erdc.usace.army.mil*. Mail correspondence to the Environmental Laboratory, ATTN: DOTS, Dredging Research, U.S. Army Engineer Research and Development Center, Waterways Experiment Station (CEERD-EM-D), 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, or call (601) 634-2349. Internet address: www.wes.army.mil/el/dots/drieb.html.


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